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MAPEAMENTO SISTÉMICO DO JOGO DE VOLEIBOL FEMININO NO ALTO NÍVEL ATRAVÉS DA ANÁLISE DE REDES SOCIAIS

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Resumo

No decorrer de qualquer evento desportivo há tarefas dinâmicas a serem levadas a cabo num contexto sistémico complexo, o que implica vários sujeitos a agirem num ambiente de competição de alta pressão caracterizado por mudanças rápidas das condições da performance desportiva. Tal realidade é ainda mais vincada nos desportos coletivos, convidando a que a análise da performance não se quede pela avaliação de parâmetros antropométricos, fisiológicos e biomecânicos. Assim, porque nas modalidades coletivas a escolha de indicadores de desempenho para análise é inevitavelmente mais complexa e intricada, a abordagem daquelas dentro de uma moldura teórica alinhada na Teoria Geral de Sistemas apresenta-se não só como útil, mas também aconselhável. O trabalho que aqui se apresenta elabora uma análise de uma modalidade coletiva - Voleibol Indoor - em contexto de Alta Competição, visando contribuir para um melhor entendimento das dinâmicas do jogo em questão. Os estudos aqui apresentados, ao trabalharem dentro de uma abordagem do desporto enquanto sistema complexo, utilizaram como ferramenta metodológica a Análise de Redes Sociais. Foram analisados 8 jogos de Voleibol da Fase de Grupos do Women's Grand Prix 2015 (Grupos A e B). Nestes jogos, foi escolhido fazer o registo e medição do valor de centralidade autovetor dos diversos complexos de jogo: K0 (serviço), KI (side-out), KII (transição do side-out), KIII (transição), KIV (cobertura de ataque) e KV (bola-morta). À parte dos entendimentos específicos a cada um dos complexos, a principal contribuição desta tese consiste na verificação das situações de off-system não serem marginais na dinâmica de jogo, devendo receber mais atenção por parte dos treinadores nas suas estratégias e planeamentos do jogo. No futuro, este tipo de análise sistémica e utilização de ARS, pode ser ainda desenvolvida para além dos resultados deste estudo, nomeadamente se efetuarem um registo de dados que considere uma separação por sets, equipas/seleções ou até mesmo por jogadores/posições, podendo aportar entendimentos mais profundos das dinâmicas de jogo.

Abstratct

In any given sports competition there are dynamic tasks being carried out in a complex and systemic reality, which involves several subjects acting in a high-pressure competitive environment characterized by rapidly changing conditions of sporting performance. This reality is even more striking in team sports, bringing about the need for performance analysis in these sports to be less centred on the assessment of anthropometric, physiological and biomechanical parameters. Thus, because team sports imply an unavoidably more complex and intricate choice of performance indicators for analysis, a study of the latter that makes use of a theoretical framework aligned within the General Systems Theory such as the one presented in this work, becomes not only useful, but also advisable. The work presented here carried out an analysis of a collective sport - Indoor Volleyball - within the context of High Competition, as a way to contribute to a better understanding of the dynamics of the game in question. The studies presented here, by working within an approach to Sports as a complex system, used as a methodological tool the Social Network Analysis. Eight matches of the Volleyball Group Stage of the Women's Grand Prix 2015 (Groups A and B) were analysed. In these matches eigenvector centrality was measured for the various game complexes: K0 (service), KI (side-out), KII (side-out transition), KIII (transition), KIV (attack coverage) and KV (free-ball). Besides specific insights related to each of the complexes analysed, the main conclusion of thesis is asserting that the off-systems situations are a non-marginal dynamics of the game, and must thus be the object of more attention by the coaches in the development of their game strategies and planning. Future works within this type of systemic analysis and use of SNA might be further developed beyond the scope of the results of this study by making use of a register differentiation by sets, teams/national teams or even by players, producing a further enhanced understanding of the dynamics of the game.

Lista de Abreviaturas

ARS	Análise de Redes Sociais
K0	Serviço/Serve
KI	Side-out
KII	Transição do Side-out/Side-out Transition
KIII	Transição/Transition
KIV	Cobertura de Ataque/Attack Coverage
KV	Bola-morta/Freeball and Downball
SNA	Social Network Analysis
TGS	Teoria Geral de Sistemas

I. Introdução

A. Âmbito Geral do Estudo

A análise do Desporto de Alta Competição tem vindo a crescer de forma exponencial, compreendendo hoje em dia um número cada vez maior de factores, variáveis e processos. Como consequência, o planeamento e análise do treino tornaram-se num processo esmagador para os treinadores ao exigir-lhes a compreensão de um grande número de variáveis (Salmon, 2010). A título de exemplo, marcadores fisiológicos, indicadores de desempenho táticos e técnicos, bem como características psicossociais: tudo minuciosamente estudado na tentativa de compreender melhor os factores subjacentes ao sucesso no desporto (ver Eliakim et al, 2009; Lac e Maso, 2004; Vingerhoets, Bylsma e Vlam, 2013).

Enquanto em alguns desportos individuais como, por exemplo, a natação, o desempenho desportivo é avaliado principalmente através de parâmetros antropométricos, fisiológicos e biomecânicos (Jürimäe et al., 2007), já nos desportos colectivos o estudo de performance deve implicar outras abordagens. Nestes desportos, a escolha de indicadores de desempenho para análise é mais complexa e intrincada, na medida em que não só há um maior número de variáveis relevantes que podem influenciar o resultado do jogo (número de jogadores), como as respetivas interações tendem a crescer exponencialmente (Ruiz et al., 2011; Afonso et al., 2009; Palao, Santos e Ureña, 2004).

É neste contexto de complexidade acrescida que a Teoria Geral de Sistemas (TGS) e as ferramentas de Análise de Redes Sociais (ARS) se tornam úteis. Assim sendo, antes de ser possível desenvolver a noção de sistemas complexos e as suas implicações na área específica das Ciências do Desporto, é importante definir e esclarecer alguns conceitos base, nomeadamente o de sistema e o de complexidade.

A utilização do conceito de sistema como base de construção de modelos teóricos em ciência – a chamada Teoria Geral dos Sistemas - foi desenvolvida pela primeira vez em meados do século XX por cientistas provenientes de uma variedade de campos, tais como Bertalanffy (1950) na Biologia, Boulding (1956) na Economia, Gerard (1958) na Neurofisiologia, Rapoport (1966) na Matemática, Klir (1972) nas Ciências da Informação e László (1969) na Filosofia. Trata-se de uma abordagem lógico-matemática que é aplicável a todas as ciências relacionadas com sistemas. Apesar da sua existência ter uma duração superior a cinco décadas, a ARS ainda está nos dias de hoje a tentar encontrar de que forma poderá ter um papel relevante num conjunto mais generalizado de áreas científicas, tais como as Ciências do Desporto.

Tradicionalmente, uma abordagem analítica tem como função dividir um sistema nos seus componentes mais simples, simultaneamente considerando que a introdução de uma alteração numa variável permitiria deduzir leis gerais, o que, por sua vez, iria permitir prever as propriedades do sistema sob diferentes condições (Gréhaigne, Bouthier e David, 1997). No entanto, o raciocínio acima referido não pode ser aplicado em sistemas complexos, tais como modalidades coletivas. Embora seja importante analisar separadamente as diversas componentes de uma modalidade, sejam elas físicas ou técnico-tácticas, estas não atuam sozinhas nos momentos competitivos. Assim sendo, neste tipo de sistemas, o que se apresenta como necessário é o uso de uma abordagem eco-sistémica (Gréhaigne, Bouthier e David, 1997). Estudos recentes na área da Psicologia da Aprendizagem que fazem uso de abordagens sistémicas e eco-ambientais, nomeadamente na temática da cognição incorporada, realçam a importância da relação sujeito-ambiente, afirmando que a aprendizagem ocorre em contextos dinâmicos, (Barab e Kirshner, 2001). Como tal, performance e aprendizagem devem ser vistos como sendo "limitados por características-chave do sistema organismo-ambiente" (Chow et al 2011, p.190).

As primeiras aplicações de uma análise eco-sistémica nas Ciências do Desporto surgiram na área da Sociologia do Desporto. Esses primeiros estudos refletem a influência do grande desenvolvimento que houve na década de 1980 da ARS dentro das Ciências Sociais (Harris, 1989; Nixon, 1992 e 1993 Borgatti et al., 2009). Mais recentemente, estudos em Ciências do Desporto, que utilizaram a ARS como ferramenta, tiveram como objetivo entender a forma como diferentes variáveis (normas, hierarquias, coesão de grupo) afetavam as relações intra-equipa, bem como verificar e se estas variáveis estariam relacionadas com o desempenho desportivo (ver Lusher, Robins e Kremer, 2010). Considerando o Desporto como um sistema complexo, McGarry (2009) aponta seis problemas que podem afectar a análise da performance. Destes seis, dois têm uma relevância particular no tema em estudo nesta tese: a) as interações entre jogadores e/ou equipas de oposição como sendo um comportamento chave na interpretação de comportamentos em jogo, e b) o contexto no qual os comportamentos desportivos são produzidos. Ambos os pontos sublinham a importância de uma análise sistémica do desempenho desportivo e a necessidade de estudar e analisar os efeitos que surgem das interações entre variáveis e entre conjuntos de variáveis.

De facto, de acordo com Gréhaigne, Godbout e Bouthier "em qualquer desporto colectivo, os jogadores são confrontados com quatro tarefas interrelacionadas: ataque ao campo do adversário, defesa do seu próprio campo, oposição aos adversários, e cooperação com os colegas de equipa" (2001, p. 60). Assim, os conceitos de aprendizagem e performance tomados em abordagem sistémica podem e devem ser considerados como dois pilares fundamentais de qualquer atividade desportiva. Como tal, qualquer estudo que se debruce sobre a performance desportiva beneficiará de uma abordagem onde se considere a relação sistémica que existe entre o resultado da acção desejada e as suas condicionantes.

B. Âmbito Particular do Estudo

O trabalho que aqui se apresenta elabora uma análise de uma modalidade coletiva – Voleibol Indoor - em contexto de Alta Competição. O Voleibol caracteriza-se como sendo um desporto que exige uma rápida tomada de decisão. O facto de nas regras estar definido que não se pode agarrar a bola (apenas repulsar ou bater) e que o mesmo atleta não pode dar dois toques consecutivos, são os o principais factores que afetam a velocidade de reação que os atletas têm que ter, bem como o número de interligações que podem ocorrer entre jogadores. Embora seja importante estudar métodos para melhorar a tomada de decisão (ver Lorains, Ball e MacMahon, 2013) e os gestos técnicos (ver Manzanares, Palao e Ortega, 2015) como variáveis independentes da modalidade, também é importante reconhecer que essas variáveis trabalham em sistema, isto é, podem ser afectadas pelas próprias variáveis contextuais dos jogadores e as suas respectivas interações.

Como tal, seguiu-se neste trabalho uma abordagem sistémica da prática deste desporto, tendo sido utilizado para o efeito uma ferramenta dentro do universo da Análise de Redes Sociais: o valor de auto-vector. Esta abordagem teórica e metodológica permite contemplar não só a complexidade das variáveis do jogo, como também a extensa existência das suas respectivas interligações. É importante realçar que a definição e/ou descrição de um comportamento sistémico, mesmo sendo um comportamento específico de uma determinada modalidade e/ou equipa(s), irá não só melhorar a compreensão do desempenho desportivo de alto nível, como fornecerá conhecimentos úteis para que os treinadores possam exercer uma orientação de maior qualidade (Clemente et al., 2015).

Ao longo dos últimos anos o desenvolvimento científico, que tem vindo a ajudar no entendimento da performance desportiva, permitiu que os treinadores pudessem entender cada detalhe e componente do sistema que é o jogo. No caso do Voleibol, um exemplo disso é a divisão do jogo em complexos. Inicialmente o jogo apenas era dividido em KI e KII, sendo que atualmente há autores que consideram seis complexos de jogo, tal como foi considerado neste estudo.

C. Objectivo do Estudo

O objectivo do estudo foi identificar regularidades comportamentais em determinados complexos do jogo, considerando assim um conjunto de comportamentos de jogo que se estendem para além dos indicadores de desempenho tradicionais. Trabalhando dentro do universo teórico-conceptual da TGS, e recorrendo ao uso do software Gephi, as diversas variáveis do jogo foram consideradas como ‘nós’, e as suas ligações/relações foram consideradas como ‘pontes’.

Foram explorados mapeamentos sistémicos de seis complexos do jogo: serviço (K0), side-out (KI), transição do side-out (KII), transição (KIII), cobertura de ataque (KIV) e bola-morta (KV). Este estudo debruçou-se sobre um total de

125 nós e 1164 pontes, o que demonstra não só a complexidade inerente do jogo, bem como a importância de se tentar detectar os padrões típicos de cada complexo, de modo a se obter um conhecimento mais aprofundado da natureza interrelacional do jogo com vista a melhorar o rendimento desportivo do mesmo.

O trabalho aqui apresentado debruça-se sobre os complexos K0, KI, KII, KII KIV e KV, e embora KI e KII sejam dois dos complexos mais estudados na literatura (Laporta e Afonso, 2015, p.14), há poucos estudos cujo foco seja as inter-relações entre as variáveis comportamentais, algo que este estudo focaliza, independentemente do complexo que esteja a ser analisado.

D. Estrutura Geral do Trabalho

Este trabalho foi dividido em três capítulos principais: I) Introdução, II) Estudos realizados e III) Considerações Finais. No final do trabalho irá ser também apresentada uma lista de referências bibliográficas que foram utilizadas na elaboração deste trabalho.

No Capítulo I é apresentada a estrutura do trabalho, bem como uma breve descrição do seu âmbito geral e particular, e o seu objetivo (dentro de uma contextualização na área específica do Voleibol de Alto Nível).

No Capítulo II serão apresentados os dois estudos realizados no âmbito do modelo escandinavo, adoptado nesta dissertação de mestrado. Os dois artigos resultantes dos dois estudos foram submetidos e aceites para publicação, tendo o primeiro artigo sido submetido e aceite na revista *International Journal of Performance Analysis in Sport,* e o segundo na revista *Montenegrin Journal of Sports Science and Medicine*. O primeiro artigo intitula-se "Systemic Mapping of High-Level Women's Volleyball using Social Network Analysis: The Case of Serve (K0), Side-out (KI), Side-out Transition (KII) and Transition (KIII)" e foi publicado no mês de Julho de 2016 (volume 16), e o segundo artigo intitula-se "Systemic Mapping of High-Level Women's Volleyball using Social Network Analysis: The Case of Attack Coverage (KIV), Freeball and Downball (KV)" tendo sido agendado para publicação no mês de Março de 2017.

Para a realização de ambos os artigos foram analisados oito jogos da Primeira Fase de Grupos do World Grand Prix Feminino (um total de 1,264 jogadas). Os dados recolhidos foram anotados com recurso ao programa de computador Excel©, tendo sido posteriormente submetidos a uma análise estatística utilizando o programa de computador SPSS©. Em último lugar, os dados já tratados foram introduzidos no software Gephi©, através da criação de nós (total de 125) e pontes (total de 1164); também com recurso ao software Gephi© foram calculados os valores de centralidade de autovetor para cada variável que depois foram utilizados para análise e interpretação detalhadas que são a base dos estudos aqui apresentados.

O Capítulo III remata esta dissertação apresentando uma pequena conclusão sobre o estado do conhecimento das relações sistémicas dos complexos de jogos analisados após a elaboração dos estudos incluídos nos dois referidos artigos.

II. Estudos empíricos

A) Primeiro estudo

Systemic Mapping of High-Level Women's Volleyball using Social Network Analysis: The Case of Serve (K0), Side-out (KI), Side-out Transition (KII) and Transition (KIII)

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Abstract

Competitive sports are growing in popularity at an exponential rate, with training becoming an almost overwhelming process, demanding an understanding and awareness of the effects of a great number of variables on sport performance. Thus, systemic approaches have emerged as essential for understanding the complex dynamics of performance. In this vein, Social Network Analysis (SNA) acquires particular relevance in comprehending the relationships established between different nodes. Therefore, the purpose of the present study was to analyze performance in high-level women's volleyball using SNA. A systematic mapping of four game complexes of the volleyball game was carried out using Gephi©. The analyzed complexes were: serve (K0), side-out (KI), side-out transition (KII) and transition (KIII). A total of 8 matches from the first Group Stage of the Women's World Grand Prix 2015 were viewed (1,264 rallies), and eigenvector centrality values were calculated. Results showed that most variables presented categories with relatively close eigenvector values, pointing to a diversified distribution of events. However, some categories did exhibit substantially distinct eigenvector centralities. Based on the findings of the present study, it was concluded that it was crucial to develop ways to enhance teams' abilities to play off-system, as it was the most common situation in female high-level volleyball. It was also shown that this enhancement should be carried out by providing diversity to the teams' options, as this diversity would create more uncertainty in the opponent and therefore, a higher chance of success.

Key words: off-system gameplay, performance analysis, social network analysis, volleyball

1. Introduction

Competitive sports are growing at an exponential rate, with training becoming an almost overwhelming process demanding an understanding and awareness of the effects of a great number of variables (Salmon, 2010). During the course of any sports event, critical tasks are performed within a dynamic, complex, collaborative system comprising multiple humans and sometimes artefacts (e.g. the ball), under high-pressure, complex, and rapidly changing conditions (Vickers et al., 1999). Accordingly, physiological markers, tactical and technical performance indicators, as well as psychosocial characteristics have been thoroughly studied in attempting to better understand the factors underlying success in sport (Eliakim et al., 2009; Lac and Maso, 2004; Vingerhoets, Bylsma and Vlam, 2013). In some cases, attempts are made to predict future performances. One such example is the algorithm developed by Blundell (2009) to predict the outcome of American Football matches. It should be kept in mind that, whereas in some individual sports, such as swimming, performance is evaluated mainly through anthropometrical, physiological and biomechanical parameters (Jürimäe et al., 2007), in other sports researchers should use distinct approaches. Specifically in team sports, the choice of performance indicators for analysis is both more complex and more intricate, in as much as there are a greater number of variables at play that can influence the result of the game, and their interactions grow exponentially, thereby making predictive ventures quite risky and volatile (Ruiz et al., 2011; Afonso et al., 2009; Palao, Santos and Ureña, 2004).

Any systemic analysis in sport performance involves undertaking numerous decisions about which performance indicators and/or their relationships may be relevant (O'Donoghue 2008, p. 145). However, Garganta (2009) underlined the fact that most analyses avoid systematic approaches – especially under ecological conditions –, perhaps due to the complexity involved. The amount of data involved, especially when interactions among variables are considered, naturally leads to greater obstacles in analysing and interpreting any findings (Xie et al., 2002; Mroczek et al., 2014). But what does 'systemic analysis' really mean? According to Oxford Dictionaries, a system can be defined as "a set of things working *together* as parts of a mechanism or an *interconnecting network*" (general definition). The use of systems as a theoretical model-building in science – the General System Theory – was first developed in the mid-1900s by scientists originating from a variety of fields, such as Biology (e.g. Bertalanffy, 1950), Economics (e.g. Boulding, 1956), Neurophysiology (e.g. Gerard, 1958), Mathematics (e.g. Rapoport, 1966), Computer Sciences (e.g. Klir, 1972), and Philosophy (e.g. László, 1969), just to refer to a few. According to its founders, General Systems Theory is a logical-mathematical discipline applicable to all sciences concerned with systems (Bertalanffy, 1950) that "lies somewhere between the highly-generalized constructions of pure mathematics and the specific theories of the specialized disciplines" (Boulding 1956, p. 197).

In this vein, the interest in network systems research can be found in such diverse areas as Computer Systems (e.g., Milner, 1996) or Sociology (Carrington, Scott and Wasserman, 2005). In the latter, concerns about the information flow and its structure gave rise in the first half of the 20th century to Social Network Analysis (SNA) that was a tenet of urban research in North-American (see Whyte, 1943) and African (see Mitchell, 1969) metropolises. Although in existence for over five decades, SNA is still finding a relevant role in a more widespread set of scientific areas, such as Sports Sciences (Lusher, Robins and Kremer, 2010). Writing in 2010, Lusher, Robins and Kremer reported that "recent developments in the overlap of fields, such as Sociology, Economics, Anthropology, Mathematics, Political Science, History, and Social Psychology, have seen the emergence of a new approach to analysis of complex intra-group relations" (2010, p. 213). The first applications of complex intra-group relations in Sports Science can be traced back to the 1990s in the area of Sports Sociology. These first studies in the area of Sports Science reflect the influence of the major development in the 1980s of SNA within the Social Sciences. The work of Harris (1989) on 'suited up' and 'stripped down' approaches to sport studies, and that of Nixon (1992, 1993) on the willingness of athletes to play with injuries and/or pain constitute early examples. Studies using SNA as a tool have been aiming to understand how variables affecting intra-team relationships such as norms, hierarchies (and other informal social structures), and cohesion, are related to sports performance (Lusher, Robins and Kremer, 2010).

In light of the above, and recognizing that Sports Sciences are just starting to scratch the surface regarding the potential of SNA, the specific case of women's volleyball from a systemic point of view was analysed in the present study. For the purpose, we applied SNA by taking into consideration a set of game behaviours that extend beyond the traditional performance indicators, namely those concerned with efficacy of terminal or intermediate actions. More specifically, behavioural variables and their interactions were considered. The establishment of a systemic behaviour, even if specific to a certain competition and/or team(s), would likely improve our comprehension of the intricacies of sports performance, as well as provide guidelines for coaches to deliver better guidance (Clemente et al., 2015). As such, we explored systematic mappings of four game complexes of the volleyball game, namely, serve (K0), side-out (KI), side-out transition (KII) and transition (KIII). Muñoz (2003, 2007) suggested a separation of the volleyball game in six complexes. First, K0, which consists only of the serve - the sole action of the game that does not depend on previous actions – and is the start of the play. Second, KI, which consists on receiving the serve and constructing the play after the serve (reception, set and attack); KII is considered the response to KI, and consists of block, defence, set and attack. KIII has the same elements of KII, and the same way KII is the response to KI, KIII is the response to KII. Although KI and KII are two of the most studied complexes in volleyball (Laporta and Afonso, 2015, p.14), there are few studies that focus on interrelationships between behavioural variables, such as the relative position of the setter (net or back row) and setting zone (interfering with the number and type of attack organizations that can be deployed).

2. Materials and methods

2.1. Sample

A total of eight matches from the first Group Stage of the Women's World Grand Prix 2015 were analysed. Specifically, Groups A (Brazil: 3rd place in the competition and 3rd place on the Fédération Internationale de Volleyball - FIVB ranking; Japan: 6th place in the competition and 5th on the FIVB ranking; Serbia: 8th place in the competition and 6th place on the FIVB ranking; Thailand: 9th place in the competition and 13th on the FIVB ranking) and B (Russia: 2nd place in the competition and 4th on the FIVB ranking; China: 4th place in the competition and 2nd on the FIVB ranking; Germany 7th place in the competition and 11th on the FIVB ranking Dominican Republic: 12th place in the competition and 7th on the FIVB ranking;) were observed. The observation was made on all the sets of the referred to games, but the register of the data was aggregated per game complex: overall, 29 sets and 1,264 rallies were analysed.

Instruments

The video recordings of the matches were obtained from the public domain site *youtube.com,* which offered both a lateralized view (aligned with the net) and an overview of the court.

The observers were trained in advance in order to attain proficiency and consistency on the coding data criteria register, both for intra- and inter-observer reliability calculations. For training purposes, each observer analyzed a minimum of eight games from different high-level competitions (men and women). Reliability was established with Cohen's Kappa above 0.80 for all the considered variables.

Variables

Six *game complexes* were considered, as proposed by Muñoz (2003, 2007): K0 (serve), KI (side-out), KII (side-out transition), KIII (transition), KIV (attack coverage) and KV (freeball and downball). Although only the first four complexes were fully included in this investigation, KIV and KV as a whole were reported to denote general connections with the remaining complexes. While some variables occur in several different complexes (thereby under distinct sets of constraints), others are specific to certain complexes. The K0 is an exception in as much as it has no variables in common with any of the other complexes. It is important to underline that, whenever a game action did not occur, the observer would register that moment as a non-occurring action. Therefore, categories such as *reception zone* (no first touch given in KI), *defence zone* (no first touch given in KII or KIII), *setting zone* (no second touch given in KI, KII or KIII), *attack zone* (no attack performed, or an attack gesture but with no jump, in KI, KII or KIII) and *attack tempo* (both conditions used in attack zone, plus ball sent to the opponent in another form of contact, in KI, KII or KIII) could be registered within the parameter non-occurring (NO) for any complex of the game.

For K0, the analysed variables were *serve type* (jump, jump-float or standing float) and *serve zone* (zone 1, zone 5 or zone 6) (Quiroga et al., 2010). The analysis of KI considered: *reception zone* (official zones 1 to 6); *setting zone* (following Laporta et al., 2015, and Esteves and Mesquita, 2007): A – all attack options available; B – quick attacks are possible but more difficult to deploy, and some attack combinations are inhibited; C – only slow, outside settings are possible; *attack zone* (official zones 1 to 6), and *attack tempo* (adapted from Afonso and Mesquita, 2007 and Costa et al., 2012): 1 - the attacker is in the air or jumping during or rapidly after the set; 2 - the attacker takes two steps after the set; 3 - the attacker takes three or more steps after the set. Regarding KII and KIII, the variables analyzed were: *number of blockers* (triple, double, single, or no block); *defense zone* (official zones 1 to 6, plus Other - when the dig occurs outside the court due to ball deflection by the block); *setting zone*; *attack zone*; and *attack tempo*. KIV and KV were merely registered as a whole, to denote when the previous complexes directly transitioned to attack coverage or freeball. When any variable did not occur it was catalogued as NO.

Statistical analysis

The data was registered on a worksheet created using the program Microsoft® Excel® 2015 for Windows, and was later analysed trough the statistical program IBM® SPSS® Statistics for Windows (Version 21, U.S.A.) for data quality control and exploratory cross table statistics. Finally, Social Network Analysis was performed using the software Gephi© 0.8.2-beta (Version 10.10.3, France). For this study, the eigenvector centrality on the software Gephi© was used. The insertion of the collected data in this software produced a total of 82 nodes and 808 bridges. In SNA studies different centrality measures are used. As Ruhnau (2000, p.358) stated “[t]he description of actors in social networks is often done in terms of some ‘structural features’ like the degree, closeness or betweenness of an actor. These structural features have been used to create measures of centrality for single nodes in a graph”. An additional measure of centrality that is often used is the *eigenvector centrality* (Bonacich, 1972). This concept is based on the idea that a node is more central if it is related with nodes that are themselves central. As such, the centrality of a node does not depend solely on the number of its adjacent nodes but also on their characteristics.

Despite previous testing of the instrument, we performed reliability testing specific for the set of data that was used in this investigation. For purposes of inter-observer reliability of analysis of the current sample, 28.9% (n = 365) of the rallies were reanalyzed (above the 10% suggested by Tabachnick and Fidell, 2000). Cohen's Kappa values respected the minimum value of 0.75 suggested in specialized literature (Fleiss, 2003), having ranged from 0.81 to 1.

3. Results

The overall Social Network Analysis' mapping is presented in Figure 1.

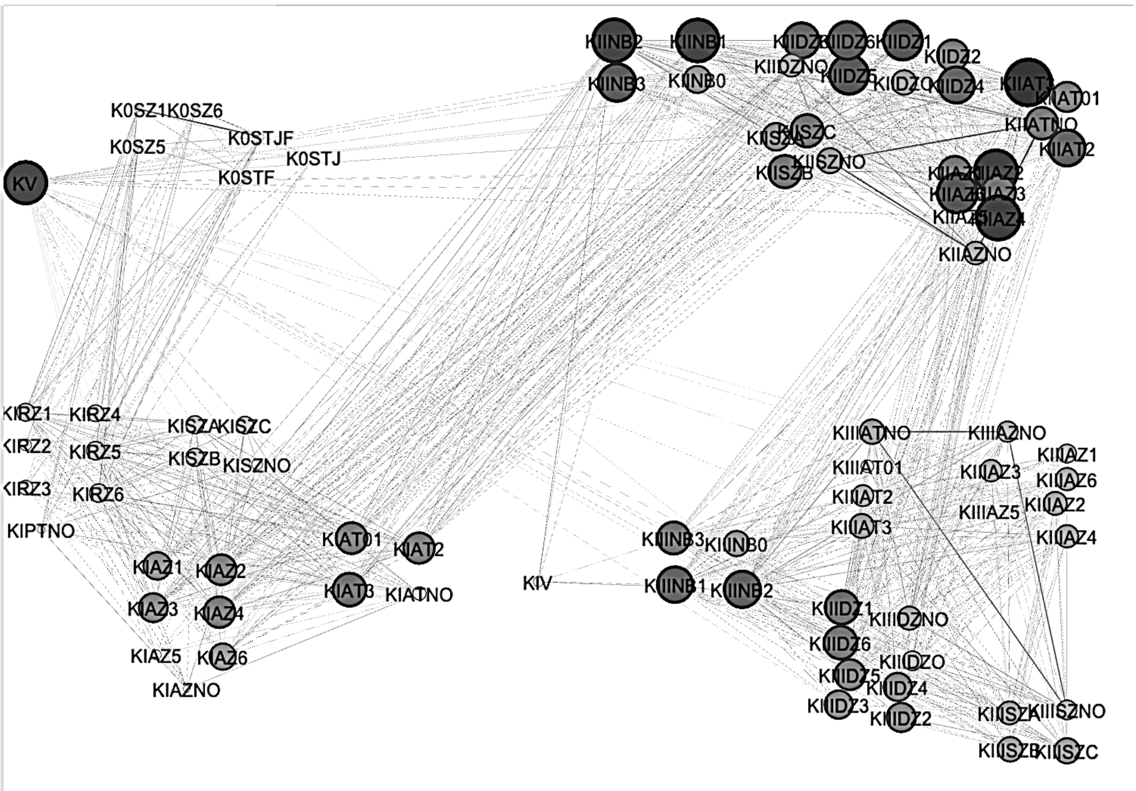

Figure 2 - K0, KI, KII and KIII Social Network Analysis' mapping (Gephi).

Concerning the first game complex, K0, the highest eigenvector value for serve type was registered in *standing float* (0.14), closely followed by *jump-float* (0.12), while the lowest value was observed in the *jump serve* (0.08). Regarding serving zones, the highest value was obtained in *zone 1* (0.12). However, both *zones 5* and *6* presented a value close to the latter (0.11) (Table 1).

Table 1- Eigenvector centrality values for K0

		Serve (K0)		
Serve Type	Jump	Jump-float	Standing Float	**Range**
	0.08	0.12	0.14	0.08 – 0.14
Serving Zone	Zone 1	Zone 5	Zone 6	**Range**
	0.12	0.11	0.11	0.11 – 0.12

Regarding KI (Table 2), the *reception zones* with the highest eigenvector values were *zones 5* and *6* (both with a value of 0.40), followed closely by *zone 1* (0.39). The lowest score was registered for the node concerning *failure to receive* (KIRZNO: 0.16). The *setting zones A* and *B* displayed a common value (0.39). Although *setting zone C* was not at the top of the values for this category, it was very close (0.38), while *failure to set* (KISZNO) had the lowest value (0.24).

Still in KI, the attack zone with the highest value for eigenvector was *zone 4* (0.68), followed closely by *zone 2* (0.66) and *zone 3* (0.63). The lowest values were registered for *zone 5* (0.21) and *failure to attack* (KIAZNO: 0.15). The three main categories within attack tempo exhibited neighboring values: *tempo 1* and *tempo 3* presented values of 0.68 and 0.72, respectively. *Non-occurring attack tempos* (KIATNO) scored the lowest value (0.29).

Table 2 - Eigenvector centrality values for KI

				Side-out (KI)				
Reception Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone Not Occurring	**Range**
	0.39	0.25	0.31	0.36	0.40	0.40	0.16	0.16 – 0.40
Setting Zone	Zone A	Zone B	Zone C	Zone Not Occurring	**Range**			
	0.39	0.39	0.38	0.24	0.24 – 0.39			
Attack Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone Not Occurring	**Range**
	0.60	0.66	0.63	0.68	0.21	0.57	0.15	0.15 – 0.68
Attack Tempo	Tempo 1	Tempo 2	Tempo 3	Tempo Not Occurring	**Range**			
	0.68	0.67	0.72	0.29	0.29 – 0.72			

Within KII (Table 3), *double* and *single blocks* had the highest eigenvector values (0.93 and 0.92, respectively), while the lowest value was scored by the *no block* variable (0.59). The defense zones with a higher eigenvector centrality value were *zones 1* and *5* (0.85). The lowest values belonged to *other defense zones* (0.53) and *failure to dig* (KIIDFNO: 0.49).

Regarding the setting zone, there was a common value of 0.71 between *setting zones B* and *C*. The lowest registered value for setting zone was for *KIISZNO* (0.55). With respect to the attack, the higher eigenvector value was obtained by *attack zone 4* (0.95) while the lowest value was found in *attack zone 5* (0.13). Within attack tempo, *tempo 3* scored the highest (1.00), while *tempo 1* scored the lowest (0.65).

Table 3 - Eigenvector centrality values for KII

	Side-out transition (KII)								
Number of Blockers	Triple	Double	Single	No block	**Range**				
	0.82	0.93	0.92	0.59	0.59 – 0.93				
Defence Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Other	Zone Not Occurring	**Range**
	0.85	0.67	0.77	0.79	0.85	0.82	0.53	0.49	0.49 – 0.85
Setting Zone	Zone A	Zone B	Zone C	Zone Not Occurring	**Range**				
	0.60	0.71	0.71	0.55	0.55 – 0.71				
Attack Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone Not Occurring	**Range**	
	0.70	0.94	0.74	0.95	0.13	0.86	0.50	0.13 – 0.95	
Attack Tempo	Tempo 1	Tempo 2	Tempo 3	Tempo Not Occurring	**Range**				
	0.65	0.79	1.00	0.70	0.65 – 1.00				

Regarding transition (KIII) (see Table 4), the most common number of blockers was *two* (KIIINB2), followed by *single block* (KIIINB1), with values of 0.79 and 0.77, respectively. Concerning the defence zone, *zones 1* (0.73) and *6* (0.72) were the highest scoring zones, with the lowest value being found for *other defence zones* (0.42). The setting zone with a higher value was *C* (0.55), while the lowest value was observed within *failure to set* (KIIISZNO: 0.42). Considering the KIII attack (zone and tempo), the highest eigenvector value registered was 0.50 (for *zone 2*), and the lowest was 0.14 (*zone 5*). Regarding attack tempo, the lowest value for eigenvector centrality was found in *attack tempo 1* (0.28), and the highest value (0.54) was registered when *attack tempo did not occur* (KIIIATNO).

Table 4 - Eigenvector centrality values for KIII

	Transition (KIII)								
Number of Blockers	Triple	Double	Single	No block	**Range**				
	0.70	0.79	0.77	0.55	0.55 – 0.79				
Defence Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Other Zone	Zone Not Occurring	**Range**
	0.73	0.63	0.61	0.61	0.66	0.72	0.42	0.51	0.42 – 0.73
Setting Zone	Zone A	Zone B	Zone C	Zone Not Occurring	**Range**				
	0.50	0.54	0.55	0.42	0.42 – 0.55				
Attack Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone Not Occurring	**Range**	
	0.40	0.50	0.47	0.49	0.14	0.49	0.45	0.14 – 0.50	
Attack Tempo	Tempo 1	Tempo 2	Tempo 3	Tempo Not Occurring	**Range**				
	0.28	0.46	0.53	0.54	0.28 – 0.54				

Finally, the eigenvector values of the two complexes that will not be developed in this paper are presented in Table 5. As it can be seen by the table presented below, KV has a much higher eigenvector value than KIV.

Table 5 - Eigenvector centrality values for KIV and KV

Attack coverage (KIV)	***Freeball or downball (KV)***
0.12	0.91

4. Discussion

Because competitive sports' training is increasingly demanding an understanding and awareness of the effects of a great number of variables on sport performance, systemic approaches have emerged as essential for understanding the complex dynamics of performance. As such, the purpose of the present study was to analyze performance per game complex in high-level women's volleyball, using Social Network Analysis. This was made by measuring the eigenvector centrality values while exploring systematic mappings of four game complexes of the volleyball game, namely the serve (K0), side-out (KI), side-out transition (KII) and transition (KIII). Results showed that most variables presented categories with relatively close eigenvector values, pointing to a diversified distribution of events. However, some categories did exhibit substantially distinct eigenvector centralities.

Performance analysis allows researchers to more fully understand the complexities surrounding performance, and therefore, to better conceptualize our teaching and training structures and guidelines (e.g. Walter, Lames and McGarry, 2007; Ericsson, 2013). It further provides coaches and athletes with an edge in improving their practices and enhancing their strengths, be it more individually (i.e., physical characteristics) or collectively (e.g., team tactics). Multidimensional variables interact within a complex and hopefully coherent system: the team (e.g. Silva et al., 2013). Understanding its interactions and systematic patterns is the purpose of a wide body of research (e.g. Travassos et al., 2013). Because using SNA as a tool allows understanding the intricate relationships established between such variables, while also allowing comprehending the impact they might have on the overall performance and outcome, in this work we sought to investigate its potential applications while studying high-level women's volleyball.

The data collected for K0 showed that the highest eigenvector value belonged to the standing float serve. It is generally known that women's teams tend to make more use of the standing float serve while men's teams make more use of the jump serve (e.g., Palao, Manzanares and Ortega, 2009), and this preference seems to develop as early as the youth level (Costa et al., 2012). It is clear that jump serves are not a part of female volleyball culture. Biologically, female athletes are on average less powerful than male athletes, therefore benefitting to a lesser extent from powerful jump serves (Palao, Manzanares and Ortega, 2009). However, it would be interesting to analyze if this is actually being produced due to cultural differences, i.e., whether there really is a relative biological disadvantage (as the net is also lower than in men's game) or a consequence of not sufficiently developing that action during the career of female athletes. The K0 data further showed that all serving zones were fairly equally distributed. We can reasonably expect that this might happen because players tend to choose their serving zone according to their starting defense location (Quiroga et al., 2010). This relation might be the reason behind the registered even distribution of serving zones.

Concerning KI, *reception zone* showed a predominance of solicitation of zones associated with longer serving trajectories (zones 1, 5 and 6). The lower values of the front row zones are likely related to both its small area (each front row zone has half the area of backcourt zones) and its closeness to the net (thereby increasing the risk of serve failure when attempting such trajectories). According to Elftmann (2012, p. 2) "though studies have been conducted in an attempt to quantify the effectiveness of serves based on speed, rotational and angular velocity, and mode of serve, the effectiveness of serving location strategies remains unknown". One interesting case obtained in these data is that of zone 4 (0.36). This case could be related with an attempt to force the opposing attacking player (for example, an outside hitter) to pass in difficult conditions and possibly impair her attack movements (Afonso et al., 2010; Lithio and Webb, 2006; López, 2013). Still in KI, *setting zone* also produced balanced eigenvector values, meaning that women's teams need to be able to build their side-out attack independently of the quality of the second contact, translating in frequent off-system play. With regard to *attack zone* in KI, front row zones expectedly presented the greatest eigenvector centrality values, while zone 5 had the lowest value, which could be explained by the usual presence of a non-attacking player (the libero) in the aforementioned zone. However, and since crossings are permitted, perhaps a greater utilization of zone 5 to attack would increase uncertainty in the opponent, expanding on the possibilities of scoring a point. The high values of zones 2 (0.66) and 1 (0.60) can probably be related to the importance attributed to the opposite hitter in scoring points (Mesquita and César, 2007; Marcelino et al., 2009), but also to the use of middle-blockers in combined attack moves (such as the 'one-foot take off'). Although studies have shown preferences in attack tempo (see Afonso et al., 2005; Mesquita et al., 2007; Castro and Mesquita, 2010), the *attack tempo* categories in this study presented instead similar values, implying that there is a relatively homogeneous distribution of their frequencies. This is consistent with the values obtained for the setting zone, and this level of values also hint at a need for women's teams to display diversity in their attacking strategies.

As in KI, the collected data in KII was fairly equally distributed within its categories, namely the *defense zone*, meaning the side-out attack uses a wide array of trajectories. Within the front row zones, there are lower eigenvector values (compared to back row values) and it is important to underline zone 2 (0.67), as it is significantly lower than zone 3 (0.77) and zone 4 (0.79). As women's teams have several technical resources to compensate for the generally less powerful form of play when compared to men's teams (Kountouris et al., 2015), it is striking that this zone is not more explored in KII. We can assume that, usually, the opposite hitter and/or the setter are responsible for zone 2, and so it would be an advantage to try to undermine both of these players' roles by putting the ball in this zone more often. The latter would work because firstly, if the setter had to carry out the first touch she would no longer be able to perform her main purpose (setting); as such, the whole team would have to adapt their attack build-up in an off-system situation. Secondly, if the opposite hitter had to make a defense, she might not be able to promptly be available for a quick attack. The eigenvector values for the *number of blockers* showed that it is rare to have a side-out transition where there is no block formation (KIINB0). The almost certain presence of block opposition presents itself as a structural characteristic of the game and is consistent with other research (Castro and Mesquita, 2008; Araújo et al., 2010). The awareness of a certain structure in the game allows for two options: a) research and development of new ways to force an off-system play (this is, KIINB0); or b) improve the already existing side-out tactics/techniques so that this structure (block) becomes less effective.

Still in KII, *setting zone* held a strong eigenvector distinction between two sets of categories. In one group setting zone A (0.60) and KIISZNO (0.55); in the other setting zones B and C (both with 0.71 eigenvector). This higher influence of setting zones B and C show that in KII playing off-system is the norm. As the setting is going to be performed under less favorable conditions, it is important to develop not only the setters' ability to do so, but also all of the other players' ability to set. Therefore, data strongly suggests that teams should regularly practice KII under non-ideal conditions, i.e., under off-system scenarios. Data on *attack zone* shows that zones 4 (0.95) and 2 (0.94) have a very high eigenvector value when compared to all other attack zones (Palao et al., 2007; Yuhong et al., 2001; Haiqiang, 2010). This overload of the outer net zones compared to the middle zone (zone 3 = 0.74) proves that the use of KII attacking zones in a more evenly distributed way could work as an advantage. The latter would come about by increasing the opponents' team uncertainty and thus force them to play in off-system situations. Although the number of players available for attack in KII may be a strong influence on the opposing's team block formation, it is important to underline that *attack tempo* could also be significant (Castro and Mesquita, 2010). As attack tempos become faster, block cohesiveness tends to diminish (Afonso and Mesquita, 2009) and therefore there is an improvement of the teams' chances to succeed through forcing an off-system situation. The high value found in attack tempo 3, linked with the highest eigenvector values found on *setting zone* (B and C) and *attack zone* (zone 2 and 4) show that there could be a certain limited, predictable pattern play in KII, improving the chances of the opposing team anticipating the events.

The eigenvector values found in KIII were generally lower than the ones found in KII. Regarding KIII's *number of blockers*, the data suggest the same kind of conclusions that were formulated for KII, namely the strong presence of block (KIIINB0=0.55) (see Table 4). Thus, a stronger presence of triple block in this complex could be an advantage, because in KII teams play with slower attack tempos, using preferentially outer attack zones, making the game more predictable. Regarding KIII *defense zone*, once again there is a fairly even distribution of values between all zones (see Table 4). KIII variable *setting zone* (see Table 4) appears more balanced than in KII (see Table 3). It should be born in mind that not only KIII can correspond to a lengthy period of play, but also female teams tend to play longer rallies (Esper, 2003). As such, the setting zones' even distribution of the eigenvector values might correspond precisely to a high volume of ball in play. The highest value collected for KIII (see Table 4) variable *attack zone* was zone 2 (0.50), followed closely by zone 4 and zone 6 (both with 0.49). It is important to underline that zone 3 also registered an eigenvector value close to the two latter zones (see Table 4). The high eigenvector value of KIIIAZ3 may be a result of a) a more balanced presence of setting zone A (see Table 4), combined with b) a possible tendency for setters to take more risks when in difficult conditions (setting zones B and C high eigenvector), and/or c) a higher availability of middle-blockers to perform an offensive action. The high eigenvector value for KIIIAZNO (0.45) (see Table 4) reflects the high number of ending KIII rallies in female volleyball. The former eigenvector value can then be linked to the *attack tempo* data, specifically KIIIATNO (0.54). The latter attack tempo is in fact the highest value found within this variable (see Table 4), most likely a result of KIII being the last complex of a rally. The data displayed in Table 5, shows that there is a much higher presence of KV (0.91), when compared to KIV (0.12). These values although not developed here, will be explored in an additional study.

5. Conclusions

This study showed that the use of SNA for performance analysis is a powerful tool. Its use in this sports performance-centered study through eigenvector measurement, allowed analyzing a high number of game variables (fifteen altogether) and respective categories (a total of eighty-two) within four game complexes. As stated at the beginning of this paper, high-level sports training is becoming an almost overwhelming process demanding an understanding and awareness of the effects of a great number of variables. This study analysed a high number of elements present in female high-level volleyball through SNA and successfully produced new knowledge on factors of play-game. The findings of this study have underlined the importance of several factors, namely the importance of classifying and analyzing the volleyball game by its complexes. The relevance of proceeding in this manner is supported by the data collected in as much as its analysis showed that different complexes have different characteristics. The study also allowed to realize that future studies of these complexes and their systemic characteristics during play would benefit from including as register variable the match status. Although an analysis that would be based on a higher volume of play/matches/rallies would be able to enlarge the understanding of the systemic features of female volleyball here presented, by collecting the data by complexes and respective variables and categories, the study here presented allowed new understandings of the female volleyball game's dynamics to emerge. Namely, the data showed that it is crucial to develop ways to enhance teams' abilities to play off-system, as it is the most common situation in female high-level volleyball. The data also showed this enhancement should be carried out by providing diversity to the teams' options, as this diversity would create more uncertainty in the opponent and therefore, a higher chance of success.

6. References

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B) Segundo estudo

Systemic Mapping of High-Level Women's Volleyball using Social Network Analysis: The Case of Attack Coverage, Freeball and Downball

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Abstract

This work analyzed team sports as complex systems where behavioural variables need to be taken into consideration when studying performance. Within this understanding, the use of Social Network Analysis constitutes a useful research path. As such this research analysed two of the least studied game complexes: attack coverage and freeball and downball, in eight matches from the first Group Stage of the Women's World Grand Prix 2015, comprising a total of 1,264 rallies. Eigenvector centrality values were calculated, with each behavioural variable being counted as a node, and their connections as edges. Results showed that playing in off-system is central in both complexes, although more so in attack coverage than in freeball and downball situations. Results also showed that although freeing a higher number of players for attack action is potentially advantageous, the latter would become a disadvantage when faced with an effective blocking action and the sudden need for effective attack coverage. Overall this study showed that volleyball coaches should take off-system game moments into stronger consideration and devise a strategy of play that will turn off-system play into an advantage and not a difficulty.

Key words: off-system gameplay, performance analysis, social network analysis, volleyball

Introduction

The study of networks pervades all of Science, from Neurobiology to Statistical Physics (Strogatz, 2001). In fact, although systemic analysis has existed for several decades (see the General Systems Theory developed in the first half of the 20th century by Bertalanffy (1950) and Boulding (1956), among others), in the last two decades a wider range of scientific fields have been displaying a broader interest in research into complex systems (Strogatz, 2001). Also, recent trends in the psychology of learning, namely in embodied cognition, stress the learner-environment relationship, stating that learning takes place in dynamic contexts with the acquisition of knowledge occurring as a consequence of indeterminate interactions between learners and the environment (Barab and Kirshner, 2001). As such, performance and learning should be viewed as “constrained by key features of the organism–environment system including the structure and physics of the environment, the biomechanics and morphology of individual and specific task constraints” (Chow, Davids, Hristovski, Araújo, and Passos, 2011, p.190).

Learning and performance are two tenets of any sports activity, and as such, any study of sports performance would benefit from an approach that considers the systemic relation between the desired action outcome and its constraints. Traditionally, an analytical approach in science breaks down a system into its most simple components while considering that the introduction of a change in a variable would allow the deducing of general laws, which would, in turn, allow predicting properties of the system under different conditions (Gréhaigne, Bouthier and David, 1997). However, the additive laws at play in the aforementioned deduction process do not function in complex systems making necessary the use of a systemic approach (Gréhaigne et al., 1997). Before the emergence of systemic analysis, the formal approaches used for explaining phenomena had been linear, stepwise, and sequential in nature, but formal methods relying on rational sequential logic are of limited utility for problems emerging from complex systems (Keating, Kauffman and Dryer 2001).

Sports, particularly team sports, can therefore be approached in a fruitful manner using the framework of non-linear, complex systems. Regarding such an approach to sports activity, the works of McGarry (with Anderson, Wallace, Hughes and Franks in 2002, and with Franks in 2006) and Lebed (2006 & 2007) demonstrate two different approaches. The first states that a sports contest can be considered as a non-linear and self-organizing system, based on dynamical principles. The same author also states “a dynamical system is a type of complex system, one which regularity self-organizes from within as a result of information exchanges that occur both inside and outside the system” (2006, p.48). On the other hand, Lebed (2006), in response to McGarry (2002), stated that although opponents competing could be interpreted as a symbiotic relation, and therefore as a system, such a concept “is nothing but an appearance of systematic wholeness" (2006, p.36). This impossibility of wholeness occurs, according to Lebed (2006), because of the antagonistic feature of the match itself, where each team's aim is directly opposed to the other's. As such, according to Lebed "the one case in which the game process becomes a system is a cooperative game" (2006, p.36). Independently of particular takes such as the two exemplified by the quotes above, the usefulness of a systemic approach is prevalent in team sports (McGarry 2002; Lebed 2006), in as much as there are several interactions between elements on both teams.

While taking sports as a complex system, McGarry (2009) underlines six issues that can affect performance analysis of which two are of particular relevance to this study: a) the interactions between opposing players and/or teams as being key for interpreting game behaviour, and b) the context in which sports behaviours are produced as offering important information for game analysis. Both points underline the importance of a systemic analysis in sports performance and the need for researchers to focus on the effects emerging from the interactions between variables and sets of variables. In fact, according to Gréhaigne, Godbout and Bouthier "in any team sport, players are faced with four interrelated tasks: attack on the adverse camp, defence of their own camp, opposition to opponents, and cooperation with partners" (2001, p. 60). The opposing team can thus be conceptualized as 'problem' in as much as it stands in the way of the other team's victory. Effective problem solving for complex issues will do better with an approach capable of addressing the uncertain dynamic behaviour that is characteristic of complex systems. Thus, the option for a systems approach analysis in problem solving will provide an overall consideration of the 'problem system' in which there are two critical points: (1) problems cannot be isolated from the system that is producing the problematic behaviour; and (2) the problem system cannot be understood independently from the context within which it is embedded (Keating, 2001). Taking team sports as open/complex systems and considering ineffective play action as the problem, we can see how contextual and behavioural variables need to be taken into consideration when studying ways to improve team performance.

In volleyball, different types of variables have been studied and analysed. However, few studies have focused on systemic mapping of the relationships between sets of variables (see Costa Afonso, Barbosa, Coutinho, and Mesquita. (2014) and Marcelino, Afonso, Moraes, and Mesquita. (2014) for exceptions). As Reed and Hughes (2006) stated in relation to patterns formed in open (complex) systems, “small changes to the system prompt large (nonlinear) changes in the system” (p.114). Due to this complexity, Sports Sciences have been investing in methods to enhance the training processes; one of such promising methods is Social Network Analysis (SNA). This latter method, with its foundation in the mathematical field of Topology, is useful in addressing the issue of interdependencies in the data inherent in team structures (Lusher and Robins 2010), both in quantitative (ex.: number of connections) and qualitative terms (ex.: degree and quality of connectedness). As such, SNA proves to be useful in identifying and measuring the centrality of game variables, which will deliver useful information for planning and developing team tactics and their intrinsic dynamics.

This research uses SNA to scrutinize how two often-neglected game complexes operate in high-level women’s volleyball: KIV – attack coverage, and KV – freeball and downball (two of the less studied complexes in volleyball, probably because they occur in a minor percentage of the game when compared to the other complexes). Competition in high-level volleyball has evolved to such a demanding level of performance, that every opportunity to score a point should be valued (Laporta, Nikolaidis, Thomas, and Afonso, 2015). As such, freeball and downball situations, although occurring in a smaller percentage in relation to the other game complexes, are important and should be studied so that a team can guarantee scoring in a favourable situation. In women’s volleyball it is common to have longer rally points than in men’s volleyball (Esper, 2003). The former occurs because there are several situations of KIII and KIV, where in the latter, a team can recover the ball possession after the opponents’ block. As such, it is important to study KIV, especially in women’s volleyball, because it will allow a team to regain an opportunity to score and thus produce a more efficacious sports performance.

Materials and methods

Sample

The World Grand Prix games analysed were part of two groups: Group A – Brazil (3rd place in the competition and 3rd place in the rankings of the Fédération Internationale de Volleyball - FIVB); Japan (6th place in the competition and 5th in the FIVB ranking); Serbia (8th place in the competition and 6th place in the FIVB ranking) and Thailand (9th place in the competition and 13th in the FIVB ranking). Group B – Russia (2nd place in the competition and 4th in the FIVB ranking); China (4th place in the competition and 2nd in the FIVB ranking); Germany (7th place in the competition and 11th in the FIVB ranking) and the Dominican Republic (12th place in the competition and 7th in the FIVB ranking). In the process, a total of eight matches (29 sets; 1,264 rallies) were analysed.

Instruments

The video recordings of the matches offered both a lateralized view (aligned with the net) and an overview of the court. The recordings of the eight matches were available in the public domain site youtube.com. In terms of observers involved in the study, the former were previously trained so as to guarantee consistency in the coding data criteria register, both for intra and inter-observer reliability calculations. This previous training consisted of viewing and registering eight games from different high-level competitions (men and women). A minimum level of 0.75 for Cohen’s Kappa calculation of reliability was established. All registered variables resulted in Kappa values above 0.81.

Variables

In this research six game complexes were considered (Muñoz, 2007): serve (K0), side-out (KI), side-out transition (KII), transition (KIII), attack coverage (KIV) and freeball and downball (KV); the two latter were analysed. Court zones were defined according to the FIVB game rules. Some variables occur in both complexes, while others are specific to each complex. As such, the common variables to both KIV and KV are: setting zone, attack zone and attack tempo. The variables that differentiate the two complexes are number of attackers' available pre-KIV and number of coverage lines (within KIV), and freeball or downball distinction, and ball within front row or back row of the court (within KV).

KIV is the only complex that can follow all other complexes (except for K0), as it is defined as the act of regaining ball possession immediately after the ball having been deflected by the opposing team's block and returned to the attacker's court (Laporta et al. 2015). As such, according to the latter authors and to Selinger and Ackermann-Blount (1986), the variables in KIV are: number of attackers available pre-KIV - this refers to the number of players available before the setting to attack the opposing team (register of observed data done from 1 player available up to a maximum of 4 players); number of coverage lines - this refers to the number of lines that constitute the attack coverage system (register of the observed data done from a minimum of 1 line up to a maximum of 3 lines); setting zone (register made following Laporta et al. (2015) and adapted from Esteves and Mesquita (2007): A- the setter can play with all of his attackers; B- the setter has space-time difficulties to set to the middle blocker, although he can still set quick plays to the outer players; C- the setter has only the options to set to the outer hitters); attack zone (zones 1 to 6); attack tempo (register made following Afonso and Mesquita (2007) and Costa, Afonso, Brant, and Mesquita (2012): 1- the attacker is in the air, or will be jumping during or rapidly after the setting; 2- after the setting the attacker takes two steps; 3- the attacker takes three or more steps after the setting).

The KV complex encompasses freeball situations or downball situations (Hileno and Buscà, 2012). As such, the variables of this complex are: distinction between freeball - the opponent delivers a ball with no aggressive/powerful intention, and downball - the ball has a more downwards trajectory than the freeball and can be more unpredictable; target zone of KV (attack zone - zones 2, 3 and 4; or defence zone - zones 1 to 6); setting zone, attack zone and attack tempo also are a part of KV, and have the same definition as presented above for KIV.

Statistical analysis

Social Network Analysis was performed using the measurement of eigenvector centrality. The data collected was initially registered on an Excel® worksheet and then subjected to a statistical analysis using IBM® SPSS® Statistics (Version 21, U.S.A.), in order to perform quality control and exploratory cross table statistics of the data. The eigenvector centrality measure was obtained by using the software Gephi© 0.8.2-beta (Version 10.10.3, France). The insertion of the collected data in this software produced a total of 43 nodes and 356 bridges. Eigenvector centrality (Bonacich, 1972) is a concept based on the idea that a node is more central if it is related with nodes that are themselves also central. As such, the centrality of a node does not depend solely on the number of its adjacent nodes but also on their characteristics.

Concerning reliability of the statistical procedures undertaken, and previous testing of the instrument notwithstanding, specific testing was performed. For purposes of inter-observer reliability of the analysis of the current sample, 50.9% (n = 216) of the rallies were reanalyzed (above the 10% suggested by Tabachnick and Fidell, 2000). Cohen's Kappa values respected the minimum value of 0.75 suggested in specialized literature (Fleiss, 2003), having ranged from 0.81 to 1.

Results:

The overall Social Network Analysis mapping is presented below. Concerning KIV (see Table 1), the eigenvector values obtained for the number of attackers available pre-KIV were very similar (KIVP1 with a value of 0.55, and KIVP2 and KIVP3 with a value of 0.54). Regarding the category number of coverage lines two values stood out: coverage lines with two and three lines (KIVL2=0.59 and KIVL3=0.62, respectively). Concerning setting zone, zones associated with off-system playing (i.e., under non-ideal conditions: KIVSZC=0.54 and KIVSZB=0.52) presented the highest eigenvector values. The two highest values found within attack zone belonged to KIVAZ3 and KIVAZ4 (both with a value of 0.57). Finally, within the attack tempo category, KIVATNO

(0.64) has the highest value, very much above that of KIVTA3 (0.53), the second highest register.

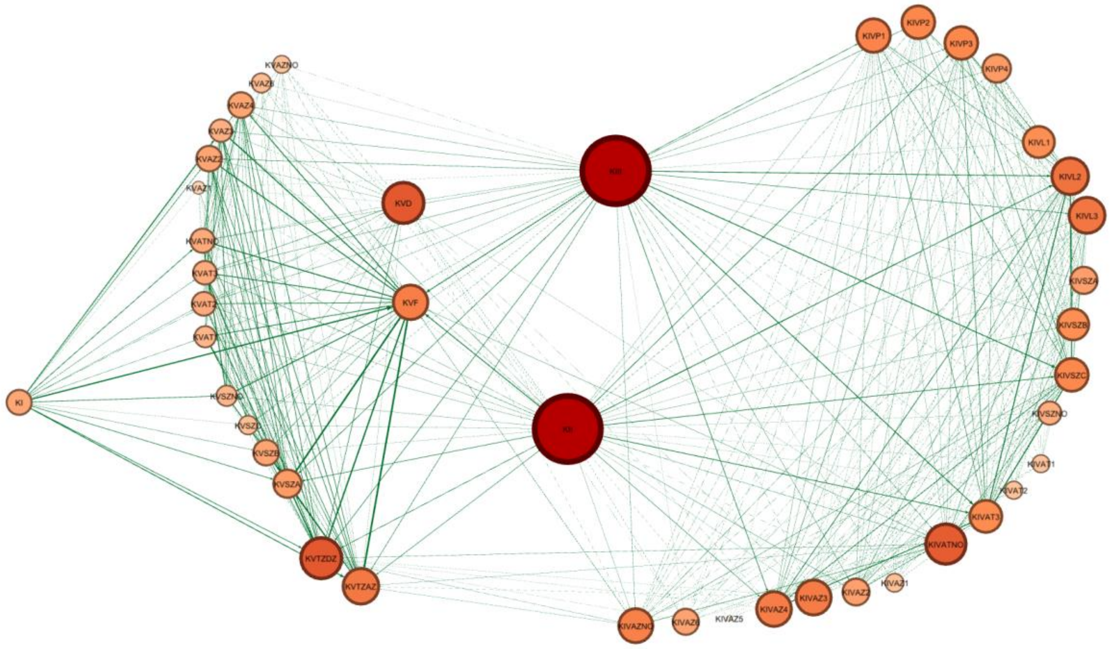

Figure1. Overall mapping of the Social Network Analysis (Gephi Software).

Table 1 - Eigenvector Values For Attack Coverage

	Attack coverage						
Number of attackers available pre-KIV (KIVP)	One attacker (KIVP1)	Two attackers (KIVP2)	Three attackers (KIVP3)	Four attackers (KIVP4)			
	0.55	0.54	0.54	0.48			
Number of coverage lines (KIVL)	One line (KIVL1)	Two lines (KIVL2)	Three lines (KIVL3)				
	0.52	0.59	0.62				
Setting Zone (KIVSZ)	SZ A (KIVSZA)	SZ B (KIVSZB)	SZ C (KIVSZC)	SZ Not Occurring (KIVSZNO)			
	0.46	0.52	0.54	0.41			
Attack Zone (KIVAZ)	AZ 1 (KIVAZ1)	AZ 2 (KIVAZ2)	AZ 3 (KIVAZ3)	AZ 4 (KIVAZ4)	AZ 5 (KIVAZ5)	AZ 6 (KIVAZ6)	AZ Not Occurring (KIVAZNO)
	0.34	0.46	0.57	0.57	0.17	0.45	0.56

Attack Tempo (KIVAT)	AT 1 (KIVAT1)	AT 2 (KIVAT2)	AT 3 (KIVAT3)	AT Not Occurring (KIVATNO)
	0.33	0.34	0.53	0.64

Regarding KV (see Table 2), the most common ball type was downball (0.65), as opposed to freeball (0.56), and the target zone that was more commonly solicited was the defensive zone (KVTZDZ=0.65). The highest eigenvector value for setting zone was found within zone A (0.48), followed by zone B (0.44). Regarding the variable attack zone, there were two zones with the same high eigenvector value (0.44), zone 2 and zone 4, followed closely by zone 3 (0.40); it is important to underline that there were no attacks performed in zone 5 and, as such, this category was excluded from the table. Regarding attack tempo all four categories presented relatively close values, with KVTA1 having the only different value from all other categories (0.38 eigenvector value, as opposed to the 0.42 found in all others).

Table 2 - Eigenvector Values For Freeball and Downball Situations

	Freeball and Downball					
Freeball or Downball (KVFOD)	Freeball (KVF)	Downball (KVD)				
	0.56	0.65				
Target Zone of KV (KVTZ)	Defense Zone (KVTZDF)	Attack Zone (KVTZAZ)				
	0.65	0.59				
Setting Zone (KVSZ)	SZ A (KVSZA)	SZ B (KVSZB)	SZ C (KVSZC)	SZ Not Occurring (KVSZNO)		
	0.48	0.44	0.35	0.37		
Attack Zone (KIVAZ)	AZ 1 (KVAZ1)	AZ 2 (KVAZ2)	AZ 3 (KVAZ3)	AZ 4 (KVAZ4)	AZ 6 (KVAZ6)	AZ Not Occurring (KVAZNO)
	0.27	0.44	0.40	0.44	0.36	0.33
Attack Tempo (KVAT)	AT 1 (KVAT1)	AT 2 (KVAT2)	AT 3 (KVAT3)	AT Not Occurring (KVATNO)		
	0.38	0.42	0.42	0.42		

To conclude, Table 3 presents the eigenvector values of the three complexes that will not be discussed in this paper. As it can be seen in the table below, KIII and KII have much higher eigenvector values than KI.

Table 3 - Eigenvector Values For Side-out, Side-out Transition And Transition

Side-out (KI)	***Transition (KII)***	***Side-out Transition (KIII)***
0.43	0.99	1.00

Discussion:

Learning and performance are tenets of any sports activity and should be viewed as being constrained by key features of the organism–environment system (Barab & Kirshner, 2001). As such, the study of sports performance would benefit from an approach that considers the systemic relation between the desired action outcome and its constraints. Therefore, while a wide body of research using Match Analysis has focused on efficacy of actions, here the focus was on behavioural aspects of performance. This paper analysed two complexes of the volleyball game, namely attack coverage (KIV) and freeball and downball (KV), in women's high-level matches. The analysis was based on SNA, namely measuring eigenvector values of each complexes' variables.

The data collected for KIV showed that, within the variable number of attackers available pre-KIV, the most common situation was having only one player available for an offensive action before an attack coverage (KIVP1=0.55). If the team that is going to be in KIV only has one player available to attack, it is more likely that the opposing team will have a more cohesive block formation in order to prevent a successful attack. The availability of only one attacker pre-KIV might promote the possibility of a routinized intention to participate in attack coverage, resulting in attributing a high importance to KIV, notwithstanding its low presence in the game. This latter characteristic should be taken into consideration in team sports coaching, as it shows that a low occurrence in the game may, nevertheless, represent an important opportunity to gain some advantage. Such a characteristic of team sports dynamics was made apparent by Lorenzo et al. (2010), as it presented situations that were less frequent but nonetheless had a direct relation to winning in U-16 male basketball (see reference to turnover in the close games category). However, the situations with two and three attackers available have registered values very close to the one attacker situation (KIVP2 and KIVP3 both with 0.54 eigenvector). The noticeable difference was when there were four attackers available (KIVP4=0.48). In this situation, the degree of uncertainty faced by the opposing block was higher. As such, the blocking action might be less effective under such constraints. Consequently, the attacking team would benefit from a situation in which there is a smaller need for attack coverage. This would be an advantage, but in case of an effective block action the attacking team by having four players in attacking mode, would not have the necessary elements available for attack coverage action.

Recent studies (such as Laporta et al., 2015) carried out on coverage lines showed this game complex is not as structured a system as previously thought. In fact, there was high variability in the disposition of the players within the coverage line(s), as this emerged as a consequence of the momentary constraints of the game, and not a structured, previously developed formation. Coverage lines thus seem to be created out of the players' availability, and this is influenced by several factors of the game both within the attacking team and the opposing team. Regarding the variable number of coverage lines, the highest eigenvector value registered in this study was found within the category two coverage lines (KIVL2=0.59). The category three coverage lines emerged as a close second (0.58), while one-line coverage had the lowest eigenvector value (0.52). This data is in agreement with the results found by Laporta et al. (2015), where the authors found the same relative frequency of coverage lines: two coverage lines occurred in 60.3% of the KIV situations, followed by three coverage lines (33.6%) and finally only one coverage line (4.7%). However, the data collected in this study showed a smaller difference in frequency of these coverage line scenarios, since all the coverage frequencies observed in this study stood much closer in range.

The results for the variable setting zone showed that in KIV the highest value belonged to setting zone C (0.54), followed by setting zone B (0.52), showing that in KIV it was more common to construct play in off-system situations. The higher presence of setting zones B and C is probably a result of the unpredictable ball deflection from the opposing block. This unpredictability results in the unavoidability of playing off-system. In fact, when following an environmental and systemic approach to team sports analysis off-system situations should be understood as highly relevant. According to Silva, Garganta, Araújo, Davids, and Aguiar, (2013, p.767) in their study on team coordination, "in most sports there is no time for team members to plan deliberately during performance, which leads to no other option than ongoing adaptation of behaviors". Thus, teams who are able to set under less favorable conditions, and also to have players (not only the setter) who are able to perform a second contact with reasonable quality would be in an advantageous position.

Concerning the variable attack zone, two categories stood out: attack zone 3 and attack zone 4 (both with an eigenvector value of 0.57). However, bordering this value was the value found in the category KIVAZNO (0.58). It was expected that, in an off-system situation, zone 4 would be a clear option, as it is an outer net zone and therefore easier to set the ball there (Castro and Mesquita, 2008). For the same reason, the high value of zone 3 comes as a surprise, as it is a central net zone, and therefore it is more difficult to set, especially with the registered higher occurrences of setting zones B and C. The fact that KIVAZNO has a high presence in the collected data shows that teams cannot perform a jumping attack very often. This means that when there is coverage, and after a first and second contact, teams would (a) return the ball to the opposing side in a non-aggressive gesture (freeball), (b) return the ball to the opposing side with some aggressive gesture, e.g., a non-jumping attack (downball) or (c) wouldn't be able to return the ball to the opposing side. A wider availability of attack zones could work as a way to increase the opponents' uncertainty and therefore could be a way to enhance the team's success. Hence coaches should practice KIV gameplay using different attack zones, either by refining the ability to set to several areas or by having more attacking players available.

Regarding attack tempo in KIV, the eigenvector value with the most influence was found in the category KIVATNO (0.64). This latter value could have the same threefold explanation as the category KIVAZNO referred to above. The second highest eigenvector value found was 0.53 (KIVAT3), representing the slowest attack tempo. It is expected that with a more off-system type of play slower attack tempos would emerge. Therefore, as a way to improve women's volleyball play in KIV, teams should practice in order to be able to use quicker attack tempos even under non-ideal conditions. These latter tempos would work as a way to unbalance the opposing block formations and consequently improve the chances of winning the point for the attacker (Afonso and Mesquita, 2009).

With respect to KV, data showed that there was a clear distinction between the eigenvector values obtained for freeball (KVF=0.56) and downball (KVD=0.65) situations. This means that when teams are forced to return the ball in less favorable conditions they play the ball in a way that creates more difficulty to the opposing team (downball). Thus, in future studies it would be an advantage to keep the distinction between these two types of ball return, as they could produce different results. Possibly, the suggestion to separate them into different game complexes would be reasonable. There is also a clear difference within the category target zone of KV as the defense zone had an eigenvector value of 0.65, compared to the 0.59 value obtained by the attack zone. This difference could be explained by the teams' need to have more time to reorganize their block and defense formations, something made easier by a longer ball trajectory.

The data collected for the category setting zone displayed zone A (0.48) as the most central category. This value could be expected in as much as the ball that is returned in freeball or downball usually has a very low degree of difficulty. Nonetheless, the values of KVSZB (0.44) and KVSZNO (0.37) were relativity close to KVSZA. The KVSZNO value emerged with some influence within KV possibly because it comprises situations where the ball was returned after a first contact and a net player would be able to attack or block the ball instantly. Although setting zone C registered the lowest value (0.35), it showed that even when the returned ball was not challenging there was still off-system playing. In future studies it might prove useful to separate downball and freeball situations in order to assess when setting zone C occurs.

For attack zone, zones 2 and 4 exhibited the highest values (both with 0.44), followed closely by zone 3 (0.40). These values show a predominant and widespread use of the front row within KV, which could be expected in association with the high value of KVSZA. It is important to underline that there were no registered attacks within zone 5 in KV, probably a result of the libero's presence. However, to explore a greater diversity of attack zones in KV, namely the use of zone 5, could become an advantage, as it would create more uncertainty to the opposing teams' block formations. Regarding attack tempo, the highest eigenvector value was 0.42, and it was found in three of the four available categories (KVAT2, KVAT3 and KVATNO). These values show that (a) even when with favorable conditions to build-up play, teams do not use the faster attack tempo available (attack tempo 1) and (b) KVATNO is related to situations where the ball is returned after a first contact (as described above in relation to KVSZNO). The KVAT2, KVTA3 and KVATNO common value could be related to the value of KVSZC. The fact that the value found within attack tempo 3 is relevant in KV, supports the fact that in KV there is also a need to play in off-system conditions, as this is the slowest tempo available and it is usually associated with setting zones B and C. These findings strengthen the argument in favor of teams increasing their use of quicker attack tempos, namely attack tempo 1, thus diminishing the opposing teams' block cohesiveness (Afonso and Mesquita, 2009).

Conclusions:

This research underlined the usefulness of SNA in high performance sports analysis in as much as it allows for the relational study of a high number of variables present in a match situation. Of particular importance, eigenvector centrality emerged as a useful metric, as it represents more than the simple number of connections each node establishes, instead weighing those connections with the number of secondary and higher-order connections. It was further demonstrated that by separating the game into different complexes distinct patterns become apparent: a fact which is relevant in helping to provide guidelines for volleyball coaching. The paper focused on two of the less studied complexes in the game – KIV and KV – and as such the data collected will be of particular usefulness for those interested in a deeper analysis of game strategies. This investigation further showed that playing in off-system conditions was frequent in both complexes, although more so in KIV than in KV; volleyball coaches should therefore take into stronger consideration the off-system game moments and devise a strategy of play that could turn off-system play in an advantage and not a difficulty.

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III. Considerações Finais

A análise do Desporto de Alta Competição compreende um número cada vez mais alargado de factores, variáveis e processos, o que tornou o planeamento e análise do treino num processo extremamente exigente para os treinadores, ao solicitar-lhes a compreensão de um grande número de variáveis (Salmon, 2010). Esta complexidade na análise da performance desportiva é acrescida no caso dos desportos colectivos, visto que a escolha dos indicadores de desempenho para análise é mais complexa e intrincada, na medida em que não só há um maior número de variáveis relevantes que podem influenciar o resultado do jogo (por exemplo, o número de jogadores), como as respetivas interações entre variáveis tendem a crescer exponencialmente (Ruiz et al., 2011; Afonso et al., 2009; Palao, Santos e Ureña, 2004). É neste contexto de complexidade acrescida que a Teoria Geral dos Sistemas (TGS) e as ferramentas de Análise de Redes Sociais (ARS) se tornam úteis.

Se as primeiras aplicações de uma análise eco-sistémica nas Ciências do Desporto surgiram na área da Sociologia do Desporto nos anos 80 do século XX, estudos realizados na primeira década do século XXI em Ciências do Desporto utilizaram a ARS como ferramenta para entender a forma como diferentes variáveis (normas, hierarquias, coesão de grupo) afetavam as relações intra-equipa, e de que modo poderiam estas variáveis estar relacionadas com o desempenho desportivo (ver Lusher, Robins e Kremer, 2010). Atualmente, não existem dúvidas quanto à utilidade dos conceitos de aprendizagem e performance quando tomados numa abordagem sistémica e o papel fundamental que têm em qualquer atividade desportiva.

O trabalho que aqui se apresentou visou a elaboração duma análise de uma modalidade coletiva – Voleibol Indoor, feminino – em contexto de Alta Competição utilizando ARS, especificamente via centralidade ponderada por cálculo de autovetor. O objectivo do estudo foi identificar regularidades comportamentais em determinados complexos do jogo, nomeadamente serviço (K0), side-out (KI), transição do side-out (KII), transição (KIII), cobertura de ataque (KIV) e bola-morta (KV), considerando assim um conjunto de comportamentos de jogo que se estendem para além dos indicadores de desempenho tradicionais. O facto de nas regras do jogo de Voleibol estar definido que não se pode agarrar a bola (apenas repulsar ou bater), e que o mesmo atleta não pode dar dois toques consecutivos, são os principais factores que implicam a alta velocidade de reação que os atletas têm que ter neste desporto (Zwierko et al., 2010), bem como o número de interligações que podem ocorrer entre jogadores. Assim, e neste contexto de elevado número de interligações, escolheu-se utilizar neste estudo uma ferramenta específica dentro do universo da ARS: o valor de autovetor. Embora esta métrica não seja inovadora, não foi, do nosso conhecimento, previamente aplicada ao tipo de problemática que abordámos ao longo deste trabalho.

Trabalhando dentro do universo teórico-conceptual da TGS, e recorrendo ao uso do software Gephi(R), as diversas variáveis do jogo foram consideradas como 'nós', e as suas ligações/relações foram consideradas como 'pontes'. Esta abordagem teórica e metodológica permitiu contemplar não só a complexidade das variáveis do jogo, como também a extensa existência das suas respectivas interligações, o que se constitui como um dos contributos mais inovadores deste estudo.

Relativamente aos resultados obtidos neste estudo, é importante realçar que em quase todos os complexos de jogo (exclui-se KI) os valores de autovetor que estão relacionados com o jogo fora-de-sistema (categoria Zona de Distribuição) foram elevados. Mesmo no único complexo em que isto não ocorreu, ou seja, em KI, a diferença entre os valores foi mínima (ver Tabela 2 do primeiro artigo). Assim, uma das conclusões que este estudo suportou de modo vigoroso foi a necessidade emergente dos treinadores contemplarem as situações fora-de-sistema como uma característica central/frequente do jogo, e não como uma vertente marginal ou esporádica do mesmo. Neste âmbito, considerando a importância das situações *off-system* que os dois estudos cabalmente demonstraram, as análises detalhadas dos complexos aqui apresentadas forneceram, igualmente, dados úteis para um melhor entendimento das dinâmicas do jogo, e para o planeamento e desenvolvimento do treino. A título de exemplo, os dados apresentados na Tabela 3 do primeiro estudo permitem ver que em KII as Zonas de Ataque mais solicitadas foram claramente Zona 4 e Zona 2, sendo que as Zonas de Distribuição B e C apresentaram também os valores mais elevados da sua categoria. Assim, em função destes dados, vantagens em jogo serão obtidas se os treinadores encontrarem formas de desenvolver o trabalho de bloco, de modo a poder ter no mínimo bloco duplo nas pontas (ver Afonso e Mesquita, 2011).

O KV é também um bom exemplo para este contexto de *off-system*, embora inicialmente possa não parecer. Este é um complexo onde supostamente a bola é devolvida para o campo adversário com um nível baixo de perigosidade; pelo próprio nome, bola-morta, bola de graça (em português do Brasil) e mesmo *freeball* (em inglês), podemos inferir que será uma situação de jogada facilitada. No entanto, os dados obtidos no segundo estudo mostram que mesmo quando uma equipa não tem organização suficiente para construir uma jogada ofensiva e devolve a bola 'morta', esta assume-se com frequência como uma bola perigosa (ver valores apresentados na Tabela 2). Isto pode ser confirmado pelo valor superior de *downball* relativamente ao valor de *freeball*, bem como da existência de valores significativos de Bola C na categoria Zona de Distribuição. Assim, na estratégia de treino, este tipo de bola deve ter uma atenção especial por parte dos treinadores, pois num jogo com uma componente decisional extrema, e uma velocidade de acção elevada (Zwierko et al., 2010), cada oportunidade para pontuar em situações de vantagem numérica deverá ser aproveitada.

Os estudos aqui apresentados e os resultados obtidos demonstraram, de modo inequívoco, a utilidade da ARS como ferramenta para o estudo das dinâmicas coletivas do Voleibol. Estudos futuros poderão potenciar ainda mais a utilidade desta ferramenta, levando a cabo um registo diferenciado por sets e/ou por equipas. Esta possível divisão poderia mostrar dados interessantes sobre as dinâmicas do jogo, como por exemplo, culturas técnico-táticas específicas de uma seleção nacional, ou até mesmo padrões de jogo específicos de cada set, pois um quinto set (por ser mais curto e por decidir o resultado final) possivelmente terá padrões diferentes de um set inicial. Estas informações técnicas mais detalhadas obtidas através da ARS, sobre uma modalidade coletiva que se insere claramente numa definição de sistema complexo, serão sem dúvida de utilidade para o desenvolvimento de uma cultura de treino cada vez mais informada e eficaz.

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